Space Weather Technical Forecast

Issued on Saturday, 25 February 2023 at 13:24 Local

This technical forecast provides a four day assessment of space weather events. The probabilities stated below are for reaching or exceeding the given levels. For more information about space weather impacts please see the Met Office Space Weather Scales https://www.metoffice.gov.uk/weather/learn-about/space-weather/uk-scales

Space Weather Forecast Headline: G1-G2 Minor to Moderate storms, and a chance G3 Strong Storms late day 2 or day 3 (26th/27th) due to CME arrival. R1-R2 Blackouts likely throughout, with a slight chance R3.

Analysis of Space Weather Activity over past 24 hours

Solar Activity: Moderate with 2 M-flares. Peak flare was a long period M3.7 and associated filament eruption at 25/2030 UTC from near AR3229 Csi/Beta in the northwest. This region has simplified, losing any negative umbra region, but has seen some negative penumbra development ahead of the main positive trailer, which is atypical for the northern hemisphere in SC25. A further impulsive M1 flare was observed from AR3235 Dro/Beta in the north-centre, however this region has been simplifying. The largest region is AR3234 Fki/Beta-Gamma-Delta in the northeast, however this has shown signs of simplification with consolidation of its leader spot, and a simple magnetic structure besides the persistent delta spot. AR3236 Dai/Beta-Delta is a smaller region, but the main developer, with a more complex twisted magnetic structure visible in SDO imagery above the spot and ongoing flux emergence. There are a couple of further smaller and simpler regions giving seven total regions on the disc.

The M3.7 flare produced a notable CME which was visible in both SOHO and STEREO A coronagraphs. This has been assessed as likely arriving at Earth later on the 26th or early 27th, although the majority of the material of the CME appears to pass above Earth's orbit. A further CME off the northeast has been analysed, likely from a C9 flare from AR3235. Model output is not yet available, however this is likely missing, passing above and behind the Earth.

Solar Wind / Geomagnetic Activity: Solar winds, as measured by DSCOVR and ACE at L1, showed a subtle and weak, but distinct magnetic cloud type rotation, and smooth magnetic field profile suggesting a very weak and glancing interaction from a passing CME. Otherwise solar winds eased from being elevated due to CH77/+ towards background levels. The speed declined from 500 km/s to 400 km/s with the density below average. The total IMF strength, Bt, was largely at background, soon easing from a peak of 8nT to around 5-6nT. The north-south component of the field Bz, smoothly rotated from around +8nT to -5nT, but became more variable from 25/0730 UTC. Phi angle was mainly positive throughout (away from the Sun). Geomagnetic activity was Quiet (Kp 0-2).

Energetic Particles / Solar Radiation: The high energy proton flux (greater than 10 MeV) as measured at GOES16 showed responded to the northwest quadrant M3.7 at 24/2030UTC, rising to a peak of 3.54pfu at 25/0010UTC, before gradually declining through the period, but staying above background. Higher energy channels (50MeV and 100MeV) also saw a small response. High energy electron flux (greater than 2MeV) at GOES16 was at Moderate levels, peaking of around 450pfu for a period during the UTC afternoon. The associated 24-hour electron fluence has been below the Active (1e8 integrated pfu) threshold on a near-level trend, reaching 1.61e7 integrated pfu at 25/0000 UTC.

Four-Day Space Weather Forecast Summary

Solar Activity: Moderate activity is likely, with further M-class flares (R1-R2 Radio Blackouts).

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There is a slight chance of X-class flares (R3 Radio Blackouts), predominately from AR3236 or AR3234.

Solar Wind / Geomagnetic Activity: A CME is expected to arrive at Earth at 26/1800 UTC +/- 6 hrs, due to the M3.7 flare and associated filament eruption off the northwest disc on the 24th. The bulk of the material is likely to pass above the Earth, but a more significant impact remains possible. This is likely to occur alongside a fast wind enhancement, due to the arrival of the HSS of CH79/- earlier day 2 (26th). There is also the potential for some enhancement on day 2 (25th) due to CH78/- in the southwest disc. Ongoing CME and CH influence is then expected for much of day 3 (27th), easing day 4 (28th). Mainly Quiet geomagnetic activity is expected to increase day 2 (26th) to Unsettled to Active with a chance of G1 Minor Storms due to any CH sourced enhancement. This then rising further to give a spell of G1/Minor to G2/Moderate Storms due to the CME arrival, with a chance of an isolated G3/Strong Storm interval. Any CME effects are likely to ease later day 3 (27th) and into day 4 (28th) to become Quiet with isolated Unsettled intervals.

Energetic Particles / Solar Radiation: High energy (greater than 10 MeV) proton flux is expected to gradually ease back towards background levels, especially once any CME arrival occurs. However there is a slight chance of further enhancements towards, or above the S1 Minor Storm threshold. High energy (greater than 2 MeV) electron flux, as observed by GOES-16 is expected to be Moderate at first, but dropping out from any fast wind and CME arrival. A subsequent re-enhancement is then expected at GEO as solar winds ease later in the period, with a chance of Active fluence day 4 (28th).

Figure 1a: Observed solar winds showing weak CME type rotation.

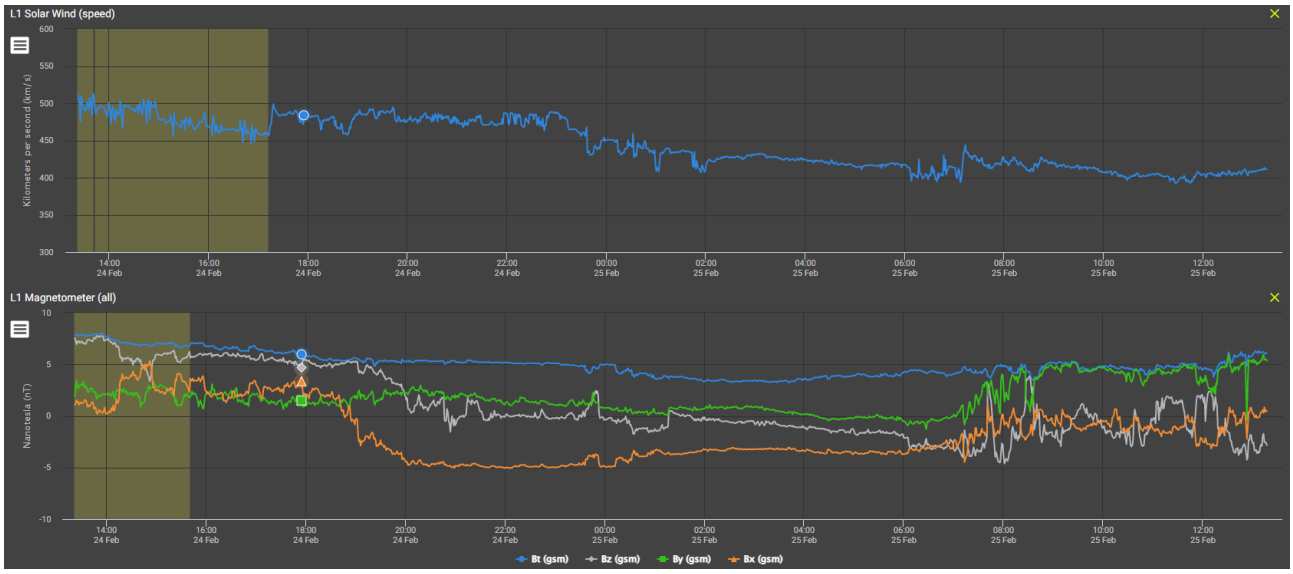

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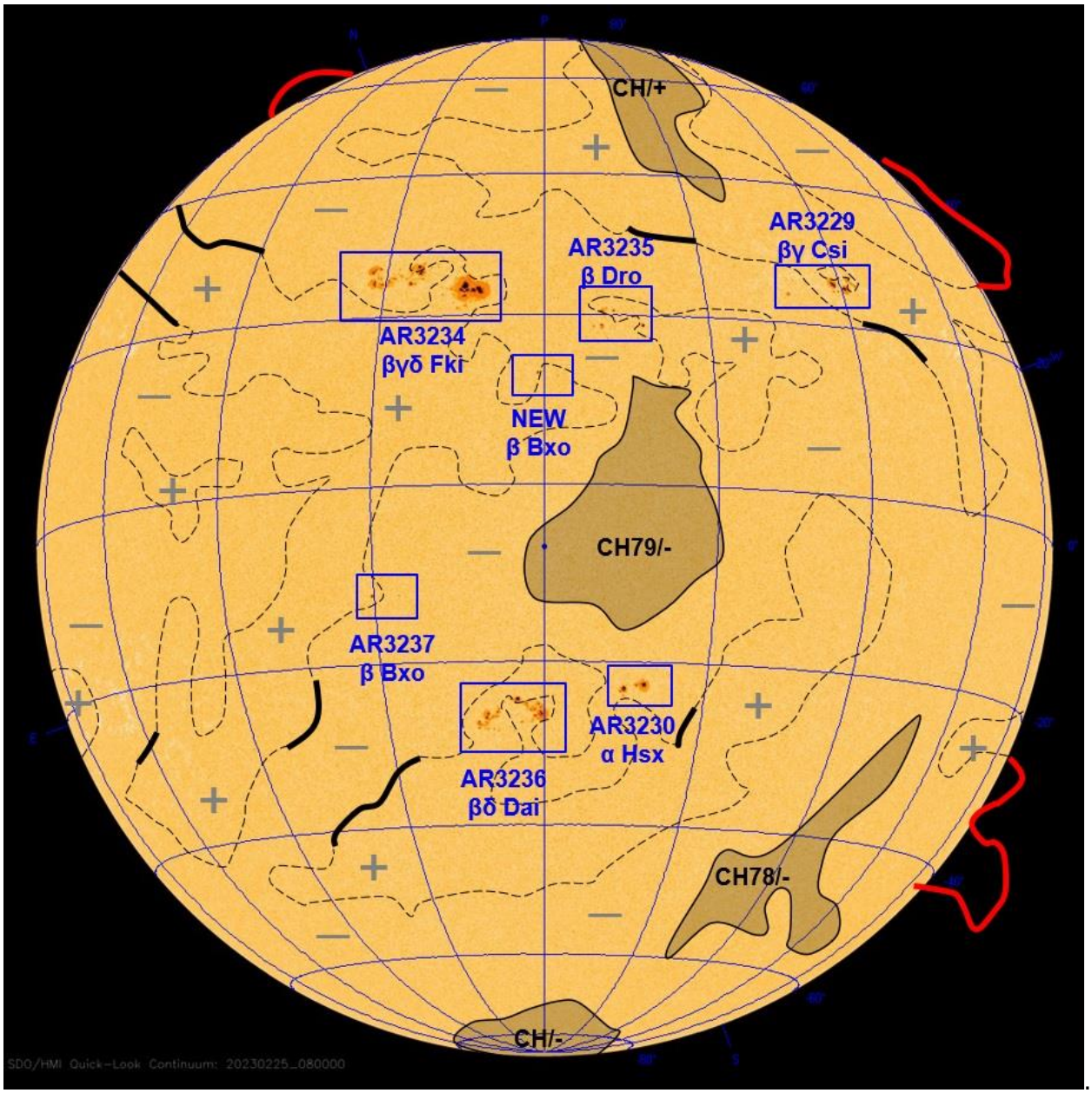
Figure 1b. Solar Analysis Valid 25/0800 UTC.



Key: Filament ___ , Prominence ___ , Magnetic Field Line - - - , Polarity +/-, Coronal Holes: Grey shaded area CHxx +/-, Sunspot groups 25xx - Mt Wilson α-β-βγ-βγδ and Zurich-McIntosh Axx etc.

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Geomagnetic Storms:

A CME which left the Sun around 24/0300 UTC due to the M3.7 flare and filament eruption near AR3229 has been analysed as having a likely arrival 26/1800 UTC +/- 6hrs. The bulk of the ejecta from this event has been modelled as passing over Earth, with a likely glancing shock arrival instead, however this is low confidence and there is the potential for a more impactful arrival.

Current background solar winds are may rise slightly in response to CH78/- in the southwest disc, however these are expected to see a more notable enhancement on day 2 (26th) due to the arrival of the fast winds of CH79/-. This high speed stream is well signaled in enlil, with model speeds up to 600km/s, and given the negative polarity of the hole and the approaching March equinox, a strong connection is likely. On the previous 27-day rotation, this feature was less strong giving peak speeds of around 500 km/s and with an equivalent arrival signaled early on day 3 (27th). STEREO A is currently giving poor guidance, as the data is contaminated with likely CME arrivals.

The onset of the fast winds, coupled with a coincident CME arrival have the potential to give a notable geomagnetic response. Consequently the initially mainly Quiet conditions are expected to increase day 2 (26th) to Unsettled to Active with a chance of G1 Minor Storms due to any CIR region ahead of the CH fast wind. This then rising further to give a spell of G1/Minor to G2/Moderate Storms due to the CME arrival, and a chance of an isolated G3/Strong Storm interval. Any CME effects are likely to ease later day 3 (27th) and into day 4 (28th) to become Quiet with isolated Unsettled intervals.

Geo-Magnetic Storm Probability (Exceedance)	Level	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC) (%)	Day 2 (00-24 UTC) (%)	Day 3 (00-24 UTC) (%)	Day 4 (00-24 UTC) (%)
Minor or Moderate	G1 to G2	No	5	70	70	30
Strong	G3	No	1	30	30	1
Severe	G4	No	1	2	1	1
Extreme	G5	No	1	1	1	1

Geomagnetic Activity - Earthbound Coronal Mass Ejections

Date/time 21.5R (UTC)	Halo: Full or Partial	Source	Source Location	Estimated Speed	Estimated Arrival Time	Comments
24/2315	Partial	M3.7 AR3229 and Filament eruption	NW	1250 km/s	26/1800 +/- 6hrs	Bulk material missing to north. Arriving during CH HSS.

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Figure 2a Enlil and Ensemble, showing CME arrival with bulk passing above Earth:

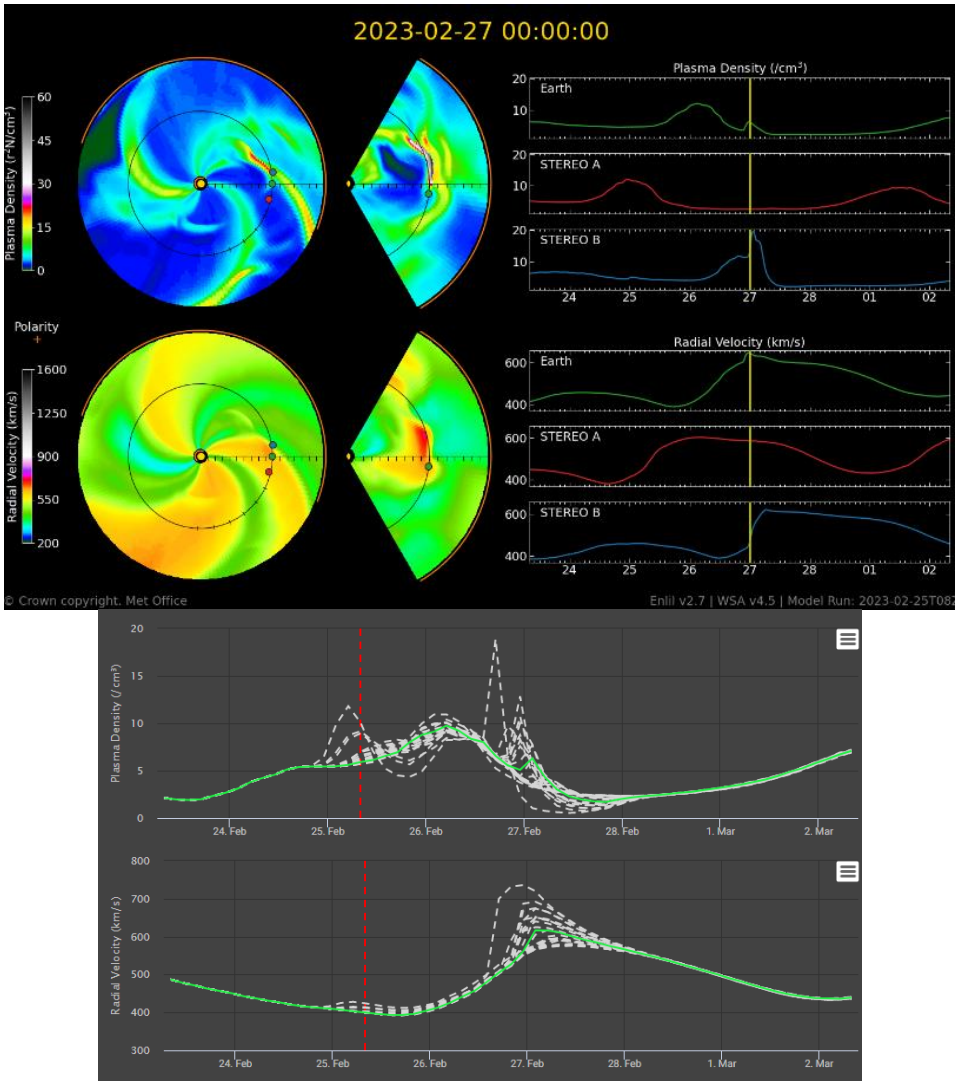
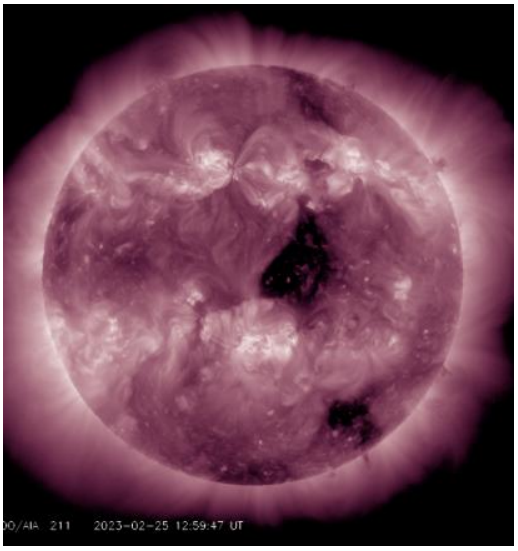


Figure 2b SDO: aia 211 showing large CH west of centre disc.



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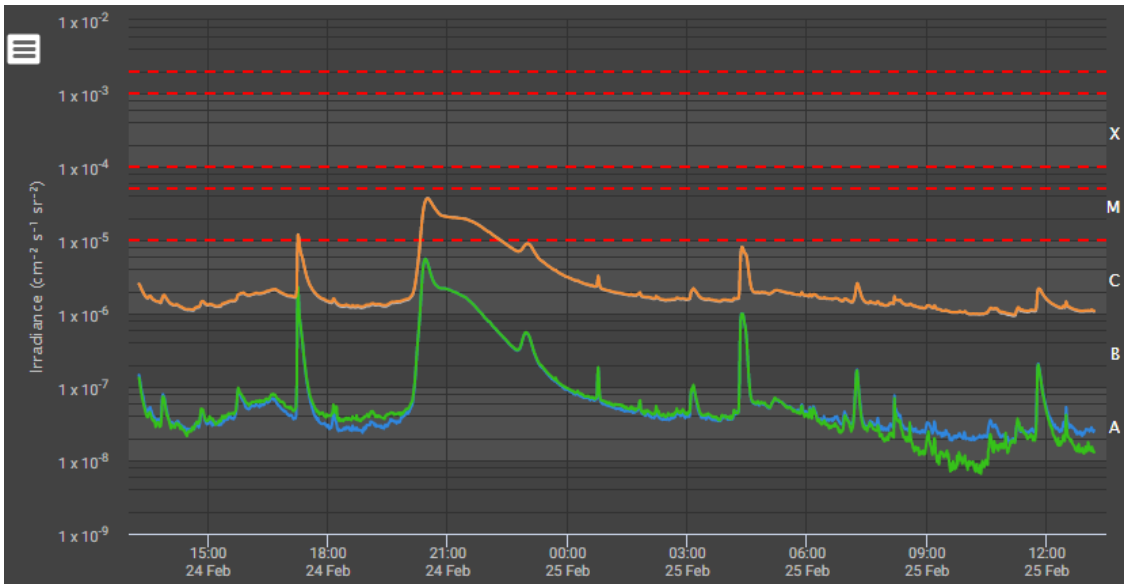
Radio Blackouts - X-Ray Flares:

Moderate activity is forecast to continue with further M-flares likely (R1-R2), and a slight chance of increasing to High with the slight chance of X-flares (R3).

There are six numbered region on the disc, three of which are currently considered candidates for notable flaring. AR3234 Fki/Beta-Gamma-Delta in the northwest is the largest region, with a strong and persistent delta spot in its broken trailing region, but has been showing consolidation of spots in its leader and a trend towards simplifying, with little magnetic twisting or shear evident in other SDO imagery. AR3236 Dai/Beta-Delta is a smaller region in the south-centre disc, but also has a strong and persistent delta evident. Despite a simpler magnetic structure on magnetogram imagery, the looping above this spot on e.g. SDO aia-171 appears more twisted and complex than the underlying spot suggests. AR3229 Cso/Beta-Gamma in the northwest is a much smaller spot, but was the source of the M3.7 flare and subsequent CME on the 24th. This has seen emergent reverse polarity flux ahead of its positive trailer, and any further growth has the potential to destablise this region further, with subsequent flaring possible.

X Ray Flares	Level	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC)	Day 2 (00-24 UTC)	Day 3 (00-24 UTC)	Day 4 (00-24 UTC)
Probability			(%)	(%)	(%)	(%)
Active	R1-R2 M Class	Yes	70	70	60	60
Very Active	R3 to R5 X Class	No	10	10	10	10

Figure 3: GOES-16/18 X-ray Flux



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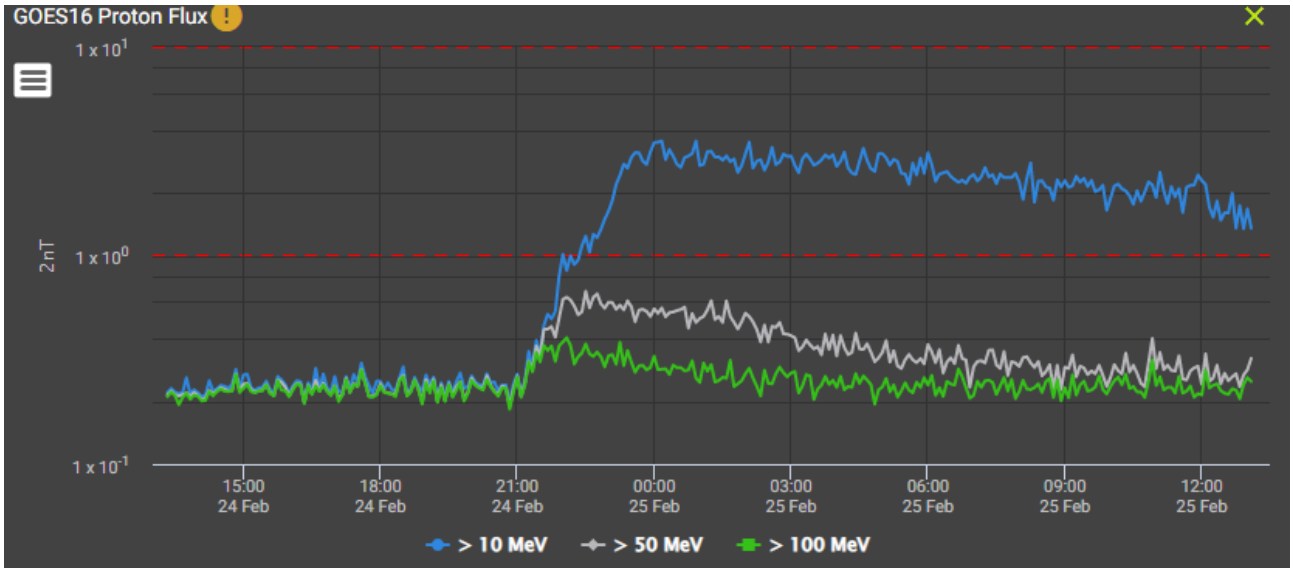
Solar Radiation Storms - (High Energy Protons):

High energy (greater than 10MeV) proton flux, as observed by GOES16, rose above background to peak at 3.54 pfu at 25/0010 UTC, in response to the long period M3.7 flare of AR3229 and associated filament eruption, along with a smaller but observable response in the very high energy channels (greater than 50MeV and greater than 100 MeV). A subsequent slow decay in count rate has been observed, and this will likely continue day 1 and 2 (25th and 26th), likely dropping to background after the arrival of the CH79 fast wind and subsequent CME.

Further proton events are possible, either from this sunspot region or from the other complex regions on the disc, including AR3234, which and AR3236 which are both moving into a more geoeffective location. This gives a slight chance of exceeding the S1 Minor Radiation Storm threshold through the period.

Radiation Storms Probability (Exceedance)	Level (cm^{-2} sr^{-1} s^{-1})	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC) (%)	Day 2 (00-24 UTC) (%)	Day 3 (00-24 UTC) (%)	Day 4 (00-24 UTC) (%)
Active	**≥ S1**	No	10	10	10	10
Very Active	**≥ S3 ***	No	1	1	1	1
* S3 ≥ 10 MeV ≥ 1000 pfu and / or ≥ 50 MeV ≥ 10 pfu. (pfu = $cm^{-2}sr^{-1}s^{-1}$)						

Figure 4: GOES-16 >10MeV, >50MeV and >100 MeV Proton Flux



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High Energy Electrons Event (≥ 2MeV):

High energy electron flux (greater than 2MeV) observed at GOES16 is currently Moderate after recent coronal hole enhancements, and unlikely to rise significantly day 1 or day 2 (25th or 26th) before the next significant arrival on day 2. This will likely be the CIR region ahead of negative polarity CH79, and then followed later on the 26th or early 27th by the expected CME arrival. These will combine to suppress observed flux at GEO, but likely increasing the electron content of the Van Allen belts which will be compressed into lower orbits. As elevated winds decline day 3 these will likely return outwards, increasing with flux increasing to Moderate, and likely to High (above 1000 pfu) by day 4 (28th).

The associated 24 hour fluence is consequently expected to persist at background days 1 and 2 (25th and 26th), but likely rising later in the period to give a chance of reaching Active day 4 (28th). REFM is currently giving good guidance up until any fast wind or CME arrival occurs on day 2 and day 3, as these will not be featured within the model.

GEO Electron Environment Probability (Exceedance)	Level (cm^{-2} sr^{-1} day^{-1})	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC) (%)	Day 2 (00-24 UTC) (%)	Day 3 (00-24 UTC) (%)	Day 4 (00-24 UTC) (%)
Active	**≥ 2 MeV ≥ $1x10^8$**	No	1	1	20	60
Very Active	**≥ 2 MeV ≥ $1x10^9$**	No	1	1	1	5

Figure 5: GOES-16 >2 MeV Electron Flux and Fluence

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